© 2018 IJSRSET | Volume 4 | Issue 4 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Wastewater Minimization of Starch Industry using Water Pinch Analysis and Comparison with Water Design Software

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ABSTRACT

The aim of the present work is waste water minimization using water pinch analysis and compares the result with water design software for a starch industry. Water pinch analysis is a graphical methodology for fresh water and waste water minimization. The results obtained using water pinch analysis formulation for water reuse of a starch industry leads to a reduction in freshwater demand of 59.16 t/hr with a fresh water pinch of 60ppm and an outlet average concentration of 224.19 ppm. The results obtained by graphical approach have been compared with water design software. It is observed from the present result that the water pinch analysis formulation technique can rapidly yield accurate minimum water targets, pinch points and the average outlet concentration of a starch industry which could be useful in management decisions. The water design software result closely matches with the graphical calculation.

Keywords: Pinch points; Starch industry; Water pinch analysis; Water design software; Wastewater minimization

I. INTRODUCTION

Water is a major stream in utility systems and in process industry. Process water can be used as solvent in direct or indirect way, transportation, cleaning and in cooling medium. Wastewater is generated in the different process and in utility systems, creating a stream which eventually needs to be treated. However in recent years the increased price of fresh water and the increased cost of wastewater treatment to meet environmental requirements have provided process industries with strong incentive to minimize the amount of water usage and wastewater generation [1,2].

The water usage of manufacturing industries varies from process to process. For a chemical manufacturing industry 4.5-45 liters of water is required per kg of product for the total process and cooling water [3]. After the process waste water is generated and the water must be treated or recycled to minimize the fresh water usage [4]. Wastewater is treated before discharge into the environment to remove contaminants to such limits that meets environmental regulations. Water treatment processes are expensive. Hence, the minimization of freshwater usage as well as wastewater generation in process systems is of great environmental and economic importance. Focusing on processes that generate wastewater in industries, ensuring proper process-to-process freshwater utilization, recycling, regeneration and reuse methodologies, have proven to minimize wastewater generation in various processing industries [5], thus achieving adequate wastewater management.

Water system integration, one of the important methodologies of wastewater minimization (otherwise known as water pinch analysis) considers how to allocate the water quantity and quality to each water using unit, so that water reuse is maximized within the system and simultaneously the wastewater generation is minimized. This method shows excellent effectiveness in saving freshwater and reducing wastewater generation [6]. Water reuse is gaining popularity throughout the world as an option for supplying a reliable alternative supply of water for applications that do not require high-quality water, freeing up limited potable water resources, while reducing effluent discharges into receiving waters [7].

Starch industry has an important economic value in the food sectors which utilizes large amount of water and generates considerable amount of waste water within the process. Common starch wastewater includes wheat, corn starch, potato starch and tapioca starch wastewater, etc. large amount of starch wastewater with discharging of pollutants at high concentrations of COD and contains suspended solids. This wastewater consumed dissolved oxygen when they entered to the fresh water, which resulted in hypoxic water. Then the fish and other aquatic organisms are getting affected. Further the discharged waste water decompose the organic matter under anaerobic conditions at bottom of the water body, generating the unpleasant odor, the water resources deteriorated, and then serious pollution to the environment should be high concerned. [8].About 40% of waste water generated from starch plant in Russia is discharged to neighboring towns [9]. Except for the quantities of water that the starch holds in or its byproducts, rest of its considered as waste water.

Generally 10 – 40 tons of corn was produced consuming large amount of fresh water, which generates waste water. There are many technologies available to save fresh water and reduce waste water generation, Water pinch is the important methodologies for wastewater minimization. Water pinch analysis has been reported by many researchers in the oil refinery, starch and other water processing industries. [10-14]

The preset work is focused on water pinch analysis. Water pinch analysis is a systematic technique for reducing water consumption and waste water generation through integration of water using activities. It is used widely as a tool for water conservation in industrial process plants. The aim of the present study is to minimize the consumption of freshwater and the generation of wastewater. In this work wastewater minimization approach is based on the concentration interval diagram and concentration composite curve method. Reuse approach has been applied for the water pinch analysis and the results were compared with water design software tool. *Water Design* is a PC-based software tool sufficient for developing many aspects of water-pinch analysis [15, 16]. Water design software tool is useful for designing the water network, determining the pinch point, minimum fresh water flow rate, and average outlet concentration for a single contaminant process. In the software tool the input data such as inlet, outlet concentration and limiting flow rate has been entered to analyze the result using water pinch analysis. Based on optimal targets for water usage, the plant's outdated water network could be updated. Water pinch method shows excellent effectiveness in saving freshwater and reducing wastewater.

II. METHODS AND MATERIAL

The study is focused on single contaminant problem of a starch industry. The Limiting process data for the starch industry is shown in the Table 1. The reuse methodology is used to reduce the waste water and the fresh water requirement using the graphical approach and the results were compared with water design software tool for the starch industry. Using the limiting process data for the respective operations the mass load has been calculated using the equation:

$$Mass\ load\ (kg/hr) = \frac{(C_{out} - C_{in}) \times f_i}{1000} \qquad (1)$$

Table 1. Limiting process data for starch Industry [17]

No	Operations	Limiting water flow rate f_i (t/hr)	Max. Limiting inlet concentration C_{in} (ppm)	Max.Limiting Outlet concentration C_{out} (ppm)	Mass load (kg/hr)
1	Primary separators(PSI)	30	1	60	1.77
2	Primary separators(PSII)	10	5	200	1.95
3	Process reactor	12	10	480	5.64
4	Dewatering section	12	15	350	4.02
5	Screens -4	5	25	50	0.125

Water Pinch Analysis –Graphical Approach

Wang and Smith [18] applied the water pinch technology on the more generalized problem of mass exchange network. The basic approach of water treatment operation is as a mass exchange problem. Later they introduce the concept of limiting water profile, concentration composite curve to determine the minimum fresh water pinch concentration. The graphical approach used to calculate the minimum fresh water flow rate of the system and to reduce the water and waste water.

III. RESULT AND DISCUSSION

Concentration-Composite Curves

The concentration-composite curves are shown in the Fig. 1, for the selected water using operations were plotted using concentration versus mass load values using the data given in the Table 1. The thick curve and the dotted line show the composite curve and water supply line respectively. These plots were used to determine the pinch points. The water supply line is plotted which starts from zero point and touches the composite curve. This point of contact is termed as pinch points. $C_{i,in,lim}$ is taken as C_{pinch} value (60ppm)for this case. To get the $C_{i,out,lim}$, the total mass load value is obtained from the Table 1. For the corresponding total mass load value, a line is marked on the composite curve which gives the $C_{i,out,lim}$. From the Fig. 1, limiting water flow rate, minimum fresh water flow rate without reuse, with reuse are determined.

Limiting water flow rate for the operation can be calculated as

$$f_{i,lim}(t/hr) = \frac{\Delta m_{i,tot}(kg/hr)}{[C_{i,out,lim}-C_{i,in,lim}](ppm)} \times 1000 \qquad (2)$$

Minimum fresh water requirement without reuse is calculated using eq(3):

$$f_{i,min}(t/hr) = \sum_i \frac{\Delta m_{i,tot}\,(kg/hr)}{C_{i,out,lim(ppm)}} \times 1000 \qquad (3)$$

Minimum fresh water requirement with reuse is calculated using the following equation:

$$f_{min}(t/hr) = \frac{\Delta m_{pinch}\ (t/hr)}{C_{pinch}\ (ppm)} \times 1000 \qquad (4)$$

Using the equation (2), (3) and (4) the $f_{i,lim}$; $f_{i,min}$ and f_{min} values are 150 t/hr; 65 t/hr ;59.16 t/hr respectively. The calculations are shown in the appendix. The average water demand by the starch before the application of the water pinch analysis is 65 t/hr is calculated using the water pinch analysis formulation (2). Table 1 shows the various water using operations of a starch industry. From the Table 1, the operations 3, 4 are high pollutant generating wastewater process whereas operations 1, 2, 5 generate relatively lower concentration wastewater. Process with lower concentration wastewater production could therefore be considered for reuse in the other operations in order to minimize the total wastewater generated and reduce freshwater utilization for such units and thereby reducing the overall freshwater demand. The results obtained using graphical approach for water reuse of a starch industry leads to reduction in fresh water demand of 59.16 (t/hr)with a fresh water pinch of 60ppm and an outlet average concentration 224.19ppm.

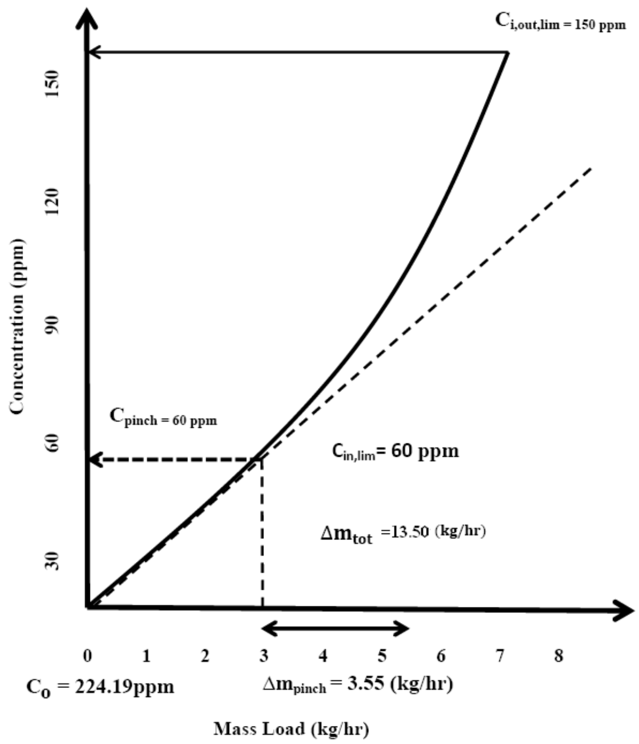

Figure 1. :Concentration composite curve (Graphical approach)

Water Design Software Tool

Water design software tool is useful for designing the water network for a single contaminant process. Fig. 2, shows the concentration-interval diagram of starch industry operation generated using water design software. It is noticed from the figure, in each concentration interval the net mass load of the contaminant to be transferred, the cumulative mass load and fresh water flow rates for each corresponding concentration level. It is further observed from the Figure 2, that the cumulative mass load for the operation at the pinch point is 3.59 kg/hr and the minimum fresh water flow rate needed for the entire operation would be 59.75 t/hr. These values are highlighted in bold in the Figure 2.

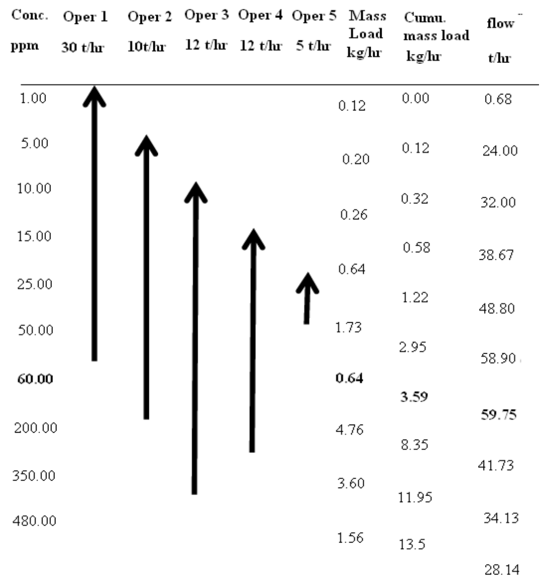

Figure 2. Concentration interval diagram for reuse approach using water design software

The concentration composite curve for the starch industry operation is shown in the Figure 3. It is noticed from the Figure 3, that the fresh water supply line (dotted line) from the origin touches the concentration composite curve at a point to determine the fresh water pinch point.

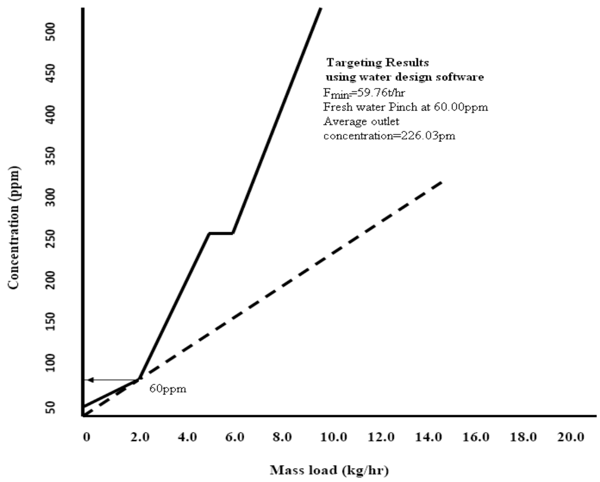

Figure 3. Concentration composite curve for reuse approach using water design software

The fresh water pinch is obtained as 60ppm which is the maximum allowable concentration level for the fresh water supply. The software tool shows that the average outlet concentration of the effluent stream for the treatment is 226.03 ppm with a corresponding mass load of 8.35 kg/hr. The mass balance for the simplified water network- reuse approach after water pinch is shown in the Figure 4 and it is noticed that the limiting inlet concentration is lower than the pinch concentration, thus it is making them to require fresh water supply of operations 1,2,3,4 and 5. The exit stream of the operation 1,5 can be used somewhere in the process as their concentration levels are below the pinch concentration (Table 1 shows the operation 1 and 5 outlet concentrations are 60ppm and 50 ppm respectively) instead of being disposed. Dark thick lines indicate the various water using operations where the waste water generated has to be disposed because of the exit concentrations are above the pinch value (60ppm). [18-20] .

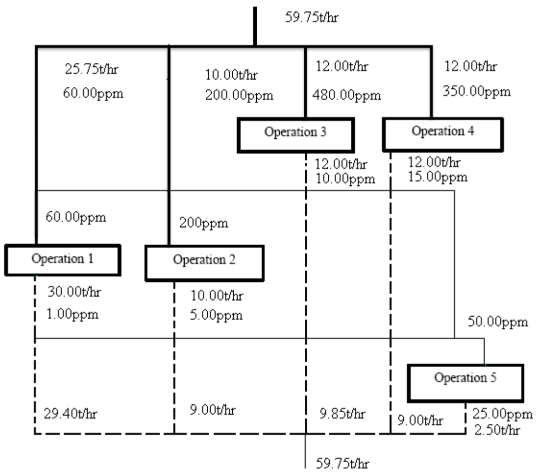

Figure 4. Mass balance for the simplified water using network –reuse approach after water Pinch using water design software

Comparison of graphical approach with water design software

The comparison of graphical approach with water design software tool is shown in the Table 2. It is observed from the table that the results obtained for the minimum freshwater requirement without reuse, minimum fresh water requirement with reuse, and the pinch points and the average outlet concentration are closely match with water design software.

Table 2. Comparison of Graphical approach and Water design software

Parameters	**Graphical approach**	**Water design software**
Minimum fresh water requirement without reuse	65 t/hr	65 t/hr
From concentration composite curve	C_{pinch} = 60 ppm	C_{pinch} = 60 ppm
	C_o = 224.19 ppm	C_o = 226.03 ppm
Minimum fresh water requirement with reuse	59.16 t/hr	59.75 t/hr

IV. CONCLUSION

A case study for water using network of a Starch industry has been studied to reduce the fresh water requirement. This has been done by reuse methodology using water pinch analysis on starch industry. The results obtained for a single contaminant problem of starch industry and the water pinch analysis formulation are compared with water design software tool. The values of limiting water flow rate, Minimum fresh water requirement without reuse and minimum fresh water requirement with reuse are 150 t/hr; 65 t/hr and 59.16 t/hr respectively. It is observed from the present work that the freshwater pinch obtained for the water using operation is at 60 ppm with the average outlet concentration of 224.19ppm. The fresh water demand is reduced from 65 t/hr to 59.16 t/hr that is around 8.98% reduction of fresh water demand. It is concluded from the present study that the water pinch analysis formulation technique can rapidly yield accurate minimum water targets, pinch points and mean outlet concentration of a starch industry. The water design software results closely match with the graphical calculation.

Appendix

Limiting water flow rate

$$f_{i,lim}(t/hr) = \frac{\Delta m_{i,tot}(kg/hr)}{[C_{i,out,lim} - C_{i,in,lim}](ppm)} \times 1000$$

$$f_{i,lim} = (\frac{13.505}{150-60})$$

$$f_{i,lim} = 150\ (t/hr)$$

Minimum fresh water requirement without reuse:

$$f_{i,min}(t/hr) = \sum_i \frac{\Delta m_{i,tot\ (kg/hr)}}{C_{i,out,lim(ppm)}} \times 1000$$

$$f_{i,min} = \left(\frac{1.77}{60} + \frac{1.95}{200} + \frac{5.64}{480} + \frac{4.02}{350} + \frac{0.125}{50}\right) \times 1000$$

$$f_{i,min} = 65\ (t/hr)$$

Minimum fresh water requirement with reuse

$$f_{min}(t/hr) = \frac{\Delta m_{pinch}\ (t/hr)}{C_{pinch}\ (ppm)} \times 1000$$

$$f_{min} = \left(\frac{3.55}{60}\right) \times 1000$$

$$f_{min} = 59.16\ (t/hr)$$

V. REFERENCES

[1]. Emongor, V., Nkegbe, E., Kealotswe, B., Koorapetse, I., Sankwasa, S., Keikanetswe, S., Pollution Indicators in Gaborone Industrial Effluent. J. of Appli.Sci, 5(1): 147-150(2005).

[2]. Kanu, I., Achi, O.K., Industrial Effluents and Their Impact on Water Quality of Receiving Rivers in Nigeria. J. of Appli. Tech. in Environmental Sanitation, 1(1): 75-86(2011).

[3]. Alva-Argaez A., Kokossis, A., Smith, R., The design of water-using systems in petroleum refining using water-pinch decomposition. Computers and Chemical Eng, 128(1):33-46(2007).

[4]. Cheremisinoff, N.P., Handbook of water and wastewater treatment technologies, Butterworth-Heinnemann, United States of America (2002).

[5]. Khezri, S.M., Lotfi, F., Tabibian, S., Erfani, Z., Application of Water Pinch Technology for Water and Wastewater Minimization in Aluminum Anodizing Industries. Int. J. Environ Sci Tech.7(2): 281-290(2010).

[6]. Majozi, T., Brouckaert, C.J., Buckley, C.A., A graphical technique for wastewater minimisation in batch processes. J of Environ Management ,78:317-329(2006) .

[7]. El-Halwagi, M.M., Gabriel, F.; Harell, D. Process Design and Control: Rigorous Graphical Targeting for Resource Conservation via Material Recycle/Reuse Networks. Ind. Eng. Chem Res. 42:4319-4328 (2003).

[8]. Zhou, G., Li, J., Fan, H., Sun, J., Zhao X., Starch Wastewater Treatment with Effective Microorganisms Bacteria, Bioinformatics and Biomedical Engineering (iCBBE), 2010 4th International Conference on 18-20 June 2010, Chengdu, China

[9]. Sklyar, V., Epov, A., Gladchenko, M., Danilovich, D., Kalyuzhnyi, S., Combined Biologic (Anaerobic-Aerobic)and Chemical Treatment of Starch Industry Wastewater, Applied Biochemistry and Biotechnology, 109:253-262(2003).

[10]. Mohammadnejad, S., Nabibidhendi, G.R., Mehrdradi, N., Water and wastewater minimization in petroleum refinery through water pinch analysis single and double contaminant approach, Research journal of environmental sciences ,5: 88-104(2012).

[11]. Mohammadnejad. S., NabiBidhendi. G.R., Mehrdadi. N., Water pinch analysis in oil refinery using regeneration reuse and recycling consideration, Desalination, 265: 255-265(2011).

[12]. Shahin, M., Abtin, A., Gholam Reza Nabi, B., Naser, M., Fatemeh, E., Fatemeh L., Water pinch analysis for water and wastewater minimization in Tehran oil refinery considering three contaminants, Environ Monit Assess, 184:2709–2728 (2012)

[13]. Dominic, C.,Yee, F., State-of-the-Art Review of Pinch Analysis Techniques for Water Network Synthesis, Ind. Eng. Chem. Res., 48: 5125–5159 (2009)

[14]. Dakwala, M., Mohanty, B., Bhargava, R. A Process Integration Approach to Industrial

Water Conservation: A Case Study for an Indian Starch Industry. J. of Cleaner Production, 17:1654-1662(2009).

[15]. Mann, J. G., Process Integration: Unifying Concepts, Industrial Applications and Software Implementation, Ph.D., dissertation, faculty of the Virginia Polytechnic Institute and State University (1999).

[16]. Olakunle, M.S., Ityokumbul, M.T., Industrial wastewater management: the water pinch analysis Approach. IMPACT: Int.J. of Research in Eng& Tech., 2:33-40(2014).

[17]. Dakwala, M., Mohanty, B., Bhargava. R., Waste Water Minimization of Starch Industry Using Water Pinch Technology, 3rd International Workshop on “cleaner production initiatives and challenges for a sustainable world” São Paulo – Brazil – May 18th-20th. (2011).

[18]. Wang, Y.P., smith, R., Wastewater minimization, Chem. Eng Science. 49(7):981-1006(1994).

[19]. Xiao Feng, Yang Liu, Long Huang, Chun Deng., Graphical Analysis of Process Changes for Water Minimization. Ind. Eng. Chem. Res., 48:7145–7151(2009)

[20]. Hallale, N. A new graphical targeting method for water minimisation. Advances in Environmental Research, 6: 377-390 (2002)